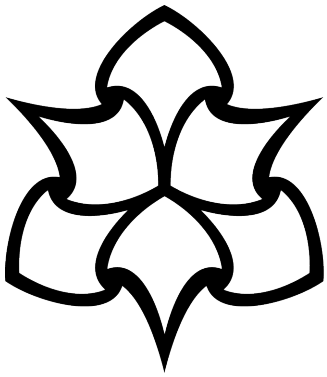


Digital Object Identifier 10.1109/ACCESS.2018.2875308

EDITORIAL

IEEE ACCESS SPECIAL SECTION EDITORIAL: ADVANCED SIGNAL PROCESSING METHODS IN MEDICAL IMAGING

Medical Imaging is a technique to create visual representations of the interior of the body, with the aim of making accurate diagnoses and optimized treatments. Many medical imaging techniques are widely used to produce images, such as computer tomography (CT), ultrasound (US), positron emission tomography (PET), single photon emission computed tomography (SPECT), and magnetic resonance imaging (MRI)/functional MRI (fMRI).

Manual interpretation and analysis of medical images is tedious and prone to error, causing overlooked, slight lesions that occasionally result in misdiagnosis. It is critical to develop advanced signal processing methods for a wide range of low-level (image reconstruction, contrast enhancement, image segmentation, etc.) and high-level applications (interpretation, classification, and grading of image findings in diagnoses, and the planning, monitoring, and evaluation of treatment) in medical imaging for accurate diagnosis and personalized treatment. These applications need novel, advanced techniques in the areas of, but not limited to, computer vision, artificial intelligence/machine learning/pattern recognition, and evolution algorithm and optimization.

This Special Section in IEEE ACCESS aims to collect a diverse and complementary set of articles that demonstrate new developments and applications of advanced signal processing in medical imaging. It will help both physicians and radiologists in the image interpretation, and help technicians to exchange the latest technical progresses.

Our Call for Papers received an enthusiastic response with more than 100 high-quality submissions. Per IEEE ACCESS policy, it was ensured that handling editors did not have any potential conflict of interest with authors of submitted articles. All articles were reviewed by at least two independent referees. The articles were evaluated for their rigor and quality, and also for their relevance to the theme of the Special Section. After a rigorous review process, we accepted 20 articles in the Special Section.

(1) In the article "multiple sclerosis detection based on biorthogonal wavelet transform, RBF kernel principal component analysis, and logistic regression," Wang *et al.* proposed a novel method on the hardware of magnetic resonance imaging to detect multiple sclerosis (MS) diseases early. Their algorithm was on the software of three successful methods: biorthogonal wavelet transform, kernel principal component analysis, and logistic regression. The materials were 676 MR slices containing plaques from 38 MS patients, and 880 MR slices from 34 healthy controls. The statistical analysis showed their method achieved a sensitivity of 97.12±.14%, a specificity of 98.25±0.16%, and an accuracy of 97.76±0.10%. Their developed method was superior to five state-of-the-art approaches in MS detection.

(2) In the article "Processing and 3D printing of gradient heterogeneous bio-model based on computer tomography images," Li *et al.* developed a digitally designing and manufacturing system for gradient heterogeneous 3-D printing. The molar model of PLY format was composed based on the CT images, and a novel method for the gradient heterogeneous material model design based on the material distribution control function and the sliced edge rings was proposed. The point color slicing algorithm based on the topological structure was achieved. Based on the system, the authors prepared a gradient heterogeneous dental model. The algorithm used for constructing and slicing of the molar model could store the geometry and material information effectively, and maintain the compatibility for the heterogeneous 3-D printer. The system supplied a fast and integrating method for the heterogeneous 3-D bio-model printing.

(3) In the article entitled "Multilinear principal component analysis network for tensor object classification", Wu *et al.* develop a multilinear principal component analysis network (MPCANet), which is a tensor extension of PCANet, to extract the high-level semantic features from multi-dimensional images. The extracted features largely minimized the intraclass invariance of tensor objects by making efficient use of spatial relationships within multi-dimensional images. Their proposed MPCANet outperformed traditional methods on a benchmark composed of three data sets, including the UCF sports action database, the UCF11 database, and a medical image database. It was shown that even a simple one-layer MPCANet may outperform a two-layer PCANet.

(4) In the article "A design and fabrication method for a heterogeneous model of 3D bio-printing," Shi *et al.* designed a modeling platform for a heterogeneous object (HEO) part based on a material distribution control function and hierarchical contour loop, and utilized it to characterize the material

distribution in the HEO model. The hierarchical algorithm of the point color and surface texture based on the topological structure was studied and provided the basic data for the material construction area. An HEO part was fabricated using a custom-made 3D printing system. The results showed that the digital processing method could effectively solve the problem of HEO part material definition and could realize the integrated design and manufacture of the geometry, material and function of biological parts.

(5) In the article ''Case-based statistical learning: A non-parametric implementation with a conditional-error rate SVM.'' Górriz *et al.* proposed a novel non-parametric approach of the so-called case-based statistical learning to solve a low-dimensional classification problem. This supervised feature selection scheme analyzed the discrete set of outcomes in the classification problem by hypothesis-testing and makes assumptions on these outcome values to obtain the most likely prediction model at the training stage. A novel prediction model was described in terms of the output scores of a confidence-based support vector machine classifier under class-hypothesis testing. The estimation of the error rates from a well-trained support vector machine allowed the authors to propose a non-parametric approach avoiding the use of Gaussian density function-based models in the likelihood ratio test.

(6) In the article ''Extended PCJO for the detection-localization of hypersignals and hyposignals in CT images,'' Chen *et al.* aimed to improve the clinical relevance of the existing model observer (MO), and they proposed an anthropomorphic MO that can also deal with hyposignals. In a previous study, the authors have reported a perceptually relevant channelized joint observer (PCJO) for detecting and localizing multiple signals with unknown amplitude, orientation, size, and location. Here, the authors extended it mathematically to hyposignals task. A free-response study (close to the real-diagnostic procedure) for both hypersignals and hyposignals in cerebral and abdominal CT images was conducted with four radiologists. The equally weighted alternative free-response operating characteristic was used as the figure of merit. The results demonstrated that the extended PCJO was an alternative to replace radiologists for the evaluation and comparison of different medical image processing algorithms. The coherent results showed that the PCJO can be generalized to another modality-CT.

(7) In the article ''Spatiotemporal joint mitosis detection using CNN-LSTM network in time-lapse phase contrast microscopy images,'' Su *et al.* presented an approach to jointly detect mitotic events spatially and temporally in time-lapse phase contrast microscopy images. In particular, the authors combined a convolutional neural network (CNN) and a long short-term memory (LSTM) network to detect mitotic events in patch sequences. The CNN-LSTM network can be trained end-to-end to simultaneously learn convolutional features within each frame and temporal dynamics between frames, without hand-crafted visual or temporal feature design. Experiments showed that the CNN-LSTM network can be trained efficiently, and the authors evaluated this design by applying the network to original raw microscopy image sequences to locate mitotic events both spatially and temporally. Furthermore, the authors developed a framework to aid humans in annotating mitosis with high efficiency and accuracy in raw phase contrast microscopy images based on the joint detection results using their proposed method.

(8) In the article ''A fast low rank Hankel matrix factorization reconstruction method for non-uniformly sampled magnetic resonance spectroscopy,'' Guo *et al.* introduced a low-rank matrix factorization method that avoids singular value decomposition, to enable fast magnetic resonance spectroscopy (MRS) reconstruction without sacrificing the spectra quality. Combined with a designed parallel computing architecture, the proposed approach can speed up the computation of low-rank approach with a factor up to 150 and enables reconstructing the challenging 3-D MRS within 15 minutes.

(9) In the article ''Cerebral micro-bleed detection based on the convolution neural network with rank based average pooling'', Wang *et al.* researched on Cerebral microbleeding (CMB), which are small perivascular hemosiderin deposits from leakage through cerebral small vessels. CMBs can be visualized via the susceptibility weighted imaging (SWI). Based on the SWI, the authors proposed to use different structures of the CNN with rank-based average pooling to detect the CMB, and they compared this method to the current state-of-the-art methods. The authors found that the CNN with five layers obtained the best performance, with a sensitivity of 96.94%, a specificity of 97.18%, and an accuracy of 97.18%.

(10) In the article ''Improving low-dose CT image using residual convolutional network,'' Yang *et al.* propose a post-processing method based on deep learning and using 2-D and 3-D residual convolutional networks, in order to maintain a high image quality for low-dose scanned CT data. Experimental results and comparisons with other competing methods showed that the proposed approach can effectively reduce the low-dose noise and artifacts while preserving tissue details. It was also pointed out that the 3-D model can achieve better performance in both edge-preservation and noise-artifact suppression. Factors that may influence the model performance, such as model width, depth, and dropout, were also examined.

(11) In the article ''GPU-accelerated features extraction from magnetic resonance images,'' Tsai *et al.* proposed a new paradigm of graphics processing unit (GPU)-accelerated method to parallelize extraction of a set of features based on the gray-level co-occurrence matrix (GLCM), which may be the most widely used method. The method was evaluated on various GPU devices and compared with its serial counterpart implemented and optimized in both Matlab and C on a single machine. A series of experimental tests focused on magnetic resonance (MR) brain images demonstrated that the proposed method was very efficient and superior to its serial

counterpart, as it could achieve more than 25-105 folds of speedup for single precision and more than 15-85 folds of speedup for double precision on Geforce GTX 1080 along different size of ROIs.

(12) In the article "A practical design and implementation of a low cost platform for real time diagnostic imaging," Ravi *et al.* proposed and validated a new method of using digital signal processors (DSPs) with a specialized pipelined vision processor (PVP) embedded at the hardware level to accelerate the routinely time-consuming imaging computation. A lab prototype was built for the feasibility study and clinical validation of the proposed technique. This unique architecture of the PVP in a dual-core DSP offered a high-performance accelerated framework along with its large on-chip memory resources, and reduced the bandwidth requirement provided as an ideal architecture for reliable medical computational needs. The authors took two sets of sample studies from SPECT for validation of 27 cases of thyroid medical history and 20 cases of glomerular filtration rate of kidneys. The results were compared with definitive post-scan SIEMENS image analysis software. From the statistical results, it was clearly shown that this method achieved very superior accuracy and 250% acceleration of computational speed.

(13) In the article "A robust online saccadic eeye movement recognition method combining electrooculography and video," Ding *et al.* proposed a robust online saccade recognition algorithm, which integrated electrooculography (EOG) and video together. Initially, EOG signals and video data were collected simultaneously from eight saccadic directions. Then online active eye movement segment detection algorithm was developed to detect the effective saccadic signal from ongoing eyeball activities. Furthermore, the authors extracted features from different modalities and explored two fusion strategies, i.e., feature level fusion (FLF) and decision level fusion (DLF). In a laboratory environment, the average recognition accuracy of FLF and DLF achieved 89.37% and 89.96%, respectively, which reveals that the proposed method can improve the performance of consecutive saccade recognition in comparison with sole modality.

(14) In the article "Data-driven corpus callosum parcellation method through diffusion tensor imaging," Cover *et al.* proposed an automatic data-driven corpus callosum (CC) parcellation method, based on diffusion data extracted from diffusion tensor imaging that uses the watershed transform. Experiments compared parcellation results of the proposed method with results of three other parcellation methods on a data set containing 150 images. Quantitative comparison using the Dice coefficient showed that the CC parcels given by the proposed method has a mean overlap higher than 0,9 for some parcels and lower than 0,6 for other parcels. Poor overlap results were confirmed by the statistically significant differences obtained for diffusion metrics values in each parcel, when using different parcellation methods. The proposed method was also validated by using the CC tractography and was the only study that proposed a non-geometric approach for the CC parcellation, based only on the diffusion data of each subject analyzed.

(15) In the article "An efficient and clinical-oriented 3D liver segmentation method," Zhang *et al.* gave an efficient and semiautomatic method for segmenting the liver in clinical cases. This method was based on Couinaud's theory and automatically divided the liver segment by portal vein branches. Considering the vascular variation of individual cases, the adjustment of the portal vein branches was provided based on automatic segmentation, thus adaptability to various cases was implemented. For the final segmentation results, the portal vein blood supply of different liver segments can be confirmed by 3-D visualization, and the liver volume can be accurately estimated. Experiments showed that this liver segmentation method has good clinical value.

(16) In the article "Longitudinal brain MRI retrieval for Alzheimer's disease using different temporal information," Trojachanec *et al.* described the research made toward improving medical case retrieval for Alzheimer's Disease (AD). Their approach considered using Magnetic Resonance Images as an input for the search. To improve the retrieval process, the authors used longitudinal information extracted from the different sets of scans acquired at different time points and automatically extracted descriptors to represent input images. All experiments were performed with and without quality control (QC) to determine the influence of the errors caused by the automated processing to the results relevance. For the experiments, a total of 267 subjects from the AD Neuroimaging Initiative database with available scans at baseline, the 6-month, 12-month, and 24-month follow-ups were selected. The obtained results showed that the selection of the time points for extraction of the longitudinal information influences the retrieval performance. Results also showed that not all automatically generated descriptors lead to improvement of the results. Longitudinal volume changes provided the most relevant representation. Adding QC phase in the experiments led to improvements in all examined scenarios. The results showed that the most frequent automatically selected features are common semantic markers for AD.

(17) In the article "A porous scaffold design method for bone tissue engineering using triply periodic minimal surfaces," Shi *et al.* suggested function-based modeling is of great interest due to its accurate controllability for designing pore architectures, among the various scaffold design methods. Parameters, such as the pore size, pore shape, porosity, and channel interconnectivity, should be designed according to actual skeleton characteristics. The authors proposed an effective modeling method of trabecular bone, combining triply periodic minimal surface (TPMS) and fractal geometry. First, the surface morphology of real trabecular bone was obtained based on the binary processing of computed tomography images. Then, the fractal pore-making element using TPMS was built and constructed into a complex porous structure. Finally, the customized scaffold model was manufactured with an additive manufacturing method.

(18) In the article ''Phase-constrained parallel magnetic resonance imaging reconstruction based on low-rank matrix completion,'' Jiang *et al.* formulated the reconstruction of sparse parallel imaging with smooth phase in each coil as the completion of a low-rank data matrix, which was modeled by the k-space neighborhoods and symmetric property of samples. The proposed algorithm was compared with a calibrationless parallel magnetic resonance imaging (MRI) reconstruction method based on both simulation data and real data. The experiment results showed the proposed method had better performance in terms of MRI imaging enhancement, scanning time reduction, and denoising capability.

(19) In the article ''Improved reconstruction of low intensity magnetic resonance spectroscopy with weighted low rank Hankel matrix completion,'' Guo *et al.* investigated the problem that low-intensity spectral peaks were compromised in the reconstruction when the data are highly undersampled. The authors proposed a weighted low rank Hankel matrix (LRHM) approach to tackle this problem. A weighted nuclear norm was introduced to better approximate the rank constraint, and a prior signal space was estimated from the prereconstruction to reduce the unknowns in reconstruction. Experimental results on both synthetic and real magnetic resonance spectroscopy (MRS) data demonstrated that the proposed approach can reconstruct low-intensity spectral peaks better than the state-of-the-art LRHM method.

(20) In the article ''A weakly-supervised framework for interpretable diabetic retinopathy detection on retinal images,'' Costa *et al.* developed a new methodology based on the multiple instance learning (MIL) framework by leveraging the implicit information present on annotations made at the image level. Contrary to previous MIL-based diabetic retinopathy (DR) detection systems, the main contribution of the proposed technique was the joint optimization of the instance encoding and the image classification stages. In this way, more useful mid-level representations of pathological images could be obtained. The explainability of the model decisions was further enhanced by means of a new loss function enforcing appropriate instance and mid-level representations. The proposed technique achieved comparable or better results than other recently proposed methods, with 90% area under the receiver operating characteristic curve (AUC) on Messidor, 93% AUC on DR1, and 96% AUC on DR2, while improving the interpretability of the produced decisions.

In conclusion, we would like to sincerely thank all the authors for submitting their articles to our Special Section, and the large number of reviewers who kindly volunteered their time and expertise to help us curate a high-quality Special Section on this important and timely topic. We would also like to thank the IEEE ACCESS Editor-in-Chief Professor Michael Pecht and other staff members of IEEE ACCESS for their continuous support and guidance.

YU-DONG ZHANG, *Professor*
Department of Informatics
University of Leicester
Leicester LE1 7RH, U.K.
e-mail: yudongzhang@ieee.org

YIN ZHANG, *Professor*
School of Information and Safety Engineering
Zhongnan University of Economics and Law
Wuhan 430073, China
e-mail: yin.zhang.cn@ieee.org

ZHENGCHAO DONG, *Associate Professor*
Translational Imaging Division & MRI Unit
New York State Psychiatric Institute
Columbia University
New York, NY 10032, USA
e-mail: zd2109@columbia.edu

TI-FEI YUAN, *Professor*
Shanghai Key Laboratory of Psychotic Disorders
Shanghai Mental Health Center
School of Medicine
Shanghai Jiao Tong University
Shanghai 200240, China
e-mail: ytf0707@126.com

LIANGXIU HAN, *Professor*
School of Computing, Mathematics,
and Digital Technology (SCMDT)
Manchester Metropolitan University
Manchester M156BH, U.K.
e-mail: l.han@mmu.ac.uk

MING YANG, *Professor*
Department of Radiology
Nanjing Children's Hospital
Nanjing Medical University
Nanjing 210008, China
e-mail: yangming19710217@163.com

CARLO CATTANI, *Professor*
Engineering School (DEIM)
University of Tuscia
01100 Viterbo, Italy
e-mail: cattani@unitus.it

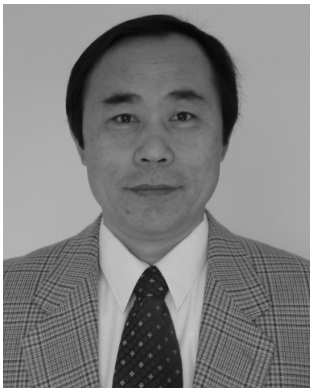
HUIMIN LU, *Professor*
Department of Mechanical and Control Engineering
Kyushu Institute of Technology
Kitakyushu 804-8550, Japan
e-mail: dr.huimin.lu@ieee.org

YU-DONG ZHANG received the Ph.D. degree from Southeast University, China, in 2010. He held a post-doctoral position from 2010 to 2012 and a Research Scientist with Columbia University, USA, from 2012 to 2013. He was a Professor with Nanjing Normal University from 2013 to 2017, where he was the Director and the Founder of Advanced Medical Image Processing Group, NJNU. Since 2017, he has been a Full Professor with the Department of Informatics, University of Leicester, U.K. His research interests are deep learning in communication and signal processing, medical image processing.

He was included in top scientist list in Guide2Research. He was included in the most cited Chinese researchers (computer science) from 2015 to 2018. In total 18 papers were included as ESI Highly Cited Papers. His citation reached 6814 with an h-index of 47 in Google Scholar and 3492 with an h-index of 36 in Web of science. He received the MDPI Top 10 Most Cited Papers 2015 and the Emerald Citation of Excellence 2017.

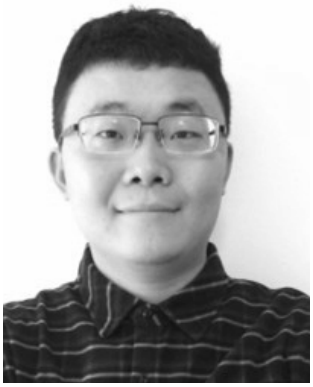
YIN ZHANG is currently an Associate Professor with the School of Information and Safety Engineering, Zhongnan University of Economics and Law (ZUEL), China. He is also a Wenlan Distinguished Scholar with ZUEL and a Chutian Distinguished Scholar, Hubei, China. He is the Vice-Chair of the IEEE Computer Society Big Data STC. He serves as an Editor or an Associate Editor for the IEEE NETWORK, the IEEE ACCESS, and the JOURNAL OF INFORMATION PROCESSING SYSTEMS. He is a Guest Editor of *Future Generation Computer Systems*, the IEEE INTERNET OF THINGS JOURNAL, *Mobile Networks and Applications* (ACM/Springer), *Sensors*, *Neural Computing and Applications*, *Multimedia Tools and Applications*, *Wireless Communications and Mobile Computing*, *Electronic Markets*, the *Journal of Medical Systems*, and *New Review of Hypermedia and Multimedia*.

He has published over 80 prestigious conferences and journal papers, including eight ESI Highly Cited Papers. He served as the TPC Co-Chair of CloudComp 2015 and the Track Chair of the IEEE CSCN 2017 and TRIDENTCOM 2017.He received the Systems Journal Best Paper Award from the IEEE Systems Council in 2018. His research interests include intelligent service computing, big data, and social network.

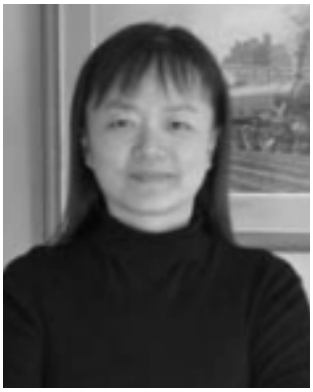


ZHENGCHAO DONG received the Ph.D. degree in physics and nuclear magnetic resonance from the University of Bremen, Germany, China, with a focus on magnetic resonance spectroscopy. He is currently an Associate professor with Columbia University Medical Center and a Research Scientist with the New York Psychiatric Institute. His main fields of research interest lie in the methodological development of magnetic resonance imaging (MRI) and their applications in mental health. These include fast MRI data acquisition and image reconstruction techniques (e.g. parallel imaging and compressed sensing), MR spectroscopic imaging techniques (e.g. proton MRSI without water suppression and MRSI quality improvement), MR temperature mapping techniques, including novel, quantitative, and multi-parametric MRI technique–magnetic resonance fingerprinting, and MRI applications in autism disorder, depression, and Alzheimer's disease.

Dr. Dong is a member of the International Society of Magnetic Resonance in Medicine. He served as a Guest Editor-in-Chief or a member of the Editorial Board of five international journals. He was a reviewer of nearly 20 journals, including *Magnetic Resonance in Medicine*, the *Journal of Magnetic Resonance Imaging*, *NeuroImage*, and *Biological Psychiatry*.



TI-FEI YUAN received the Ph.D. degree from the University of Geneva, where he is currently involved in brain plasticity in addiction and different psychiatric disorders. His group also employs non-invasive brain stimulation to manage these diseases. He is now a Professor in Shanghai Mental Health Center (SMHC), School of Medicine, Shanghai Jiao Tong University Shanghai, China.



LIANGXIU HAN received the Ph.D. degree in computer science from Fudan University, Shanghai, China, in 2002. He was with both industry and academia. She is currently a Full Professor of computer science with the School of Computing, Mathematics, and Digital Technology, Manchester Metropolitan University. She is also the Deputy Director of the Centre for Advanced Computational Science and Man Met Crime and Well-Being Big Data Centre. He has over 14 years research and practical experiences in developing intelligent ICT-enabled software solutions for large-scale data processing and data analysis and mining in different application domains (e.g. health, smart cities, bioscience, cyber security, and energy) using various data sets, such as images, sensor data, network traffic, and web pages.

He is currently a Principal Investigator or Co-PI. He has been conducting research in relation to big data processing and data mining, and cloud computing/parallel and distributed computing (funded by EPSRC, BBSRC, Innovate U.K., Horizon 2020, British Council, Royal Society, Industry, and Charity). He is a member of the EPSRC Peer Review College, an Independent Expert of Horizon 2020 Proposal Evaluation, and the British Council Peer Review Panel. He has also served as a Guest Editor for a number of reputable international journals (e.g., the IEEE ACCESS, PPNA, and the *Journal of Medical Systems*) and the Chair (or Co-Chair) for organization of a number of international conferences/workshops in the field. She has been invited to give a number of keynotes and talks on different occasions (including international conferences, and national and international institutions/organizations).

MING YANG received the M.D., the master's, and the Ph.D. degrees in medical imaging from Southeast University, Nanjing, China, in 1995, 2004, and 2011, respectively . She served as a Visiting Scholar with the Department of Radiology, University of Maryland, from 2013 to 2014. She is currently the Director of the Nanjing Children's Hospital, Nanjing Medical University, Nanjing, Jiangsu, China, since 2016. She is currently a Pediatric Committee Member of the Chinese Society of Radiology and the Chinese Medical Doctor Association of Radiology. Her research interests include functional MRI, radiomics and cardiovascular imaging, and especially in pediatric patients.

CARLO CATTANI is currently a Professor of mathematical physics and applied mathematics with the Engineering School (DEIM), University of Tuscia. His scientific interests include but are not limited to: wavelets, dynamical systems, fractals, fractional calculus, numerical methods, stochastic integro-differential equations, competition models, time series analysis, nonlinear analysis, complexity of living systems, image analysis, computational biology, and bio-physics.

HUIMIN LU received the M.S. degree in electrical engineering from the Kyushu Institute of Technology, the M.S. degree in electrical engineering Yangzhou University in 2011, and the Ph.D. degree in electrical engineering from the Kyushu Institute of Technology in 2014. From 2013 to 2016, he was a JSPS Research Fellow (DC2, PD, and FPD) with the Kyushu Institute of Technology, where he is currently an Assistant Professor and an Excellent Young Researcher of the Ministry of Education, Culture, Sports, Science, and Technology, Japan. He serves as an Editor or an Associate Editor for the IEEE ACCESS Journal and *Computers & Electrical Engineering*.

His research interests include artificial intelligence, computer vision, computational imaging, deep-sea observing, Internet of Things, and robotics. He has authored or co-authored 100+ papers in journals and conferences, which have received over 1000 citations. As the lead editor, he has edited two books and have over 40K downloads. He has received over 20 awards from the governments, associations, and international conferences. He is the Leading Guest Editor of *ACM/Springer Mobile Networks and Applications*, *Optics & Laser Technology*, and *Multimedia Tools and Applications*.